Lesson 5
Elaborate

What Is the Risk?

At a Glance

Overview
Students apply their growing understanding of the concepts of toxicology (dose, response, individual susceptibility, potency, and threshold) to their discussion of the 1950s tragedy in Minamata, Japan. They learn how to assess the risk of people to specific chemical hazards and make decisions about how to manage that risk.

Major Concepts
People can make some choices about chemical exposure; however, some exposure is controlled at a level other than an individual one. Collective groups of people, such as communities and governments, seek to control chemical exposure on a community or global level.

Objectives
After completing this lesson, students will

- use their knowledge about dose, response, individual susceptibility, and route and frequency of exposure to understand a historical situation involving hazardous chemical exposure;
- assess the risk to people in Minamata of mercury poisoning using a risk assessment flow chart;
- compare their own risk of mercury poisoning with that of the people of Minamata; and
- understand the kinds of critical choices people make about chemical exposure and that some exposure is controlled at a level other than an individual one, such as the community or global level.

Background Information

The Minamata Case Study
When people living in Minamata, Japan, in the 1950s began slurring their speech occasionally or dropping their chopsticks at a meal, no one thought much of it. Some people cruelly laughed, claiming their clumsy friends were acting like the cats that were "dancing" strangely in the street and falling to their death in the sea. When it seemed like more and more people were suffering from the mysterious lack of coordination, the community began to realize that something was seriously

wrong. But, people did not know that they were seeing the first signs of a debilitating nervous condition caused by ingesting mercury.[1]

We now know the tragic story of Minamata. The Minamata Bay was polluted with the industrial waste from the Chisso Corporation, which manufactured acetaldehyde used to make plastics. The mercury that the company used in the production process was discharged into the bay, incorporated into bacteria, and passed through the food chain to people living in the area. The people in the town were slowly being poisoned by their most important food source: fish.

The consequences of such blatant polluting seem obvious to people today. But at the time, science had not yet documented the hazards of mercury, and environmental awareness was not pervasive. In fact, the Minamata case has become a classic lesson in the tragedy of industrial pollution and the need to anticipate the unexpected consequences of introducing chemicals into the environment. Although the story is now half a century old (and "ancient history" for today's middle school students), it has a well-documented cause and effect, as well as a resolution. In this way, it provides a good model for teaching about risk assessment and management that students can apply to their analysis of current exposures to chemicals.

Minamata photographs by W. Eugene Smith and Aileen M. Smith.

Risk Assessment

Today, when toxicologists study the extent and type of negative effects associated with a particular level of chemical exposure, they can use what they learn to assess the threat of that chemical to people's health. To do this, toxicologists measure a person's risk of exposure to the chemical. For example, even though dioxin is considered the most toxic synthetic chemical known, it does not pose the greatest risk to humans because the potential for significant dioxin exposure is quite small. In addition, while the lethal dose of a chemical is an important measurement to make, it is quite possible that a chemical will produce a very undesirable toxic effect at doses that cause no deaths at all. These lower doses may be the amount to which people are regularly exposed.

How a person is exposed to a chemical also determines the factor of risk. In the case of a single exposure, the amount of chemical and way the body is known to respond to the chemical determine the severity of the toxic response. In the case of repeated exposures to a chemical, it is not only the amount of chemical that counts, but also the frequency of exposure. If the body is able to rid itself entirely of the chemical before the next exposure, it is

possible that each exposure is akin to a single exposure to the chemical. If, however, the body still retains some of the chemical from the previous exposure, accumulation of the chemical can occur and eventually can reach toxic levels, even if each exposure is small.

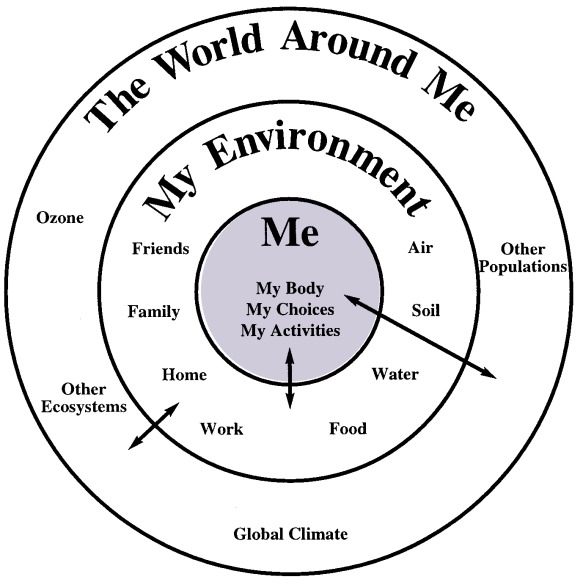
Many of the measurements that guide toxicologists in their assessment of human risk are based on studies of animals other than humans. This fact, coupled with the individual susceptibility of different members of the human population, makes it difficult to know with absolute certainty the level of risk to which each individual is exposed. With adequate information, however, toxicologists can predict the health risks associated with specific chemical exposures and help the human population make informed decisions about how to limit those exposures.

Managing Risk

The built-in uncertainty of risk assessment makes it essential for people to possess enough knowledge to make decisions about their own exposures to chemicals. With adequate knowledge, individuals can make decisions concerning their exposure to tobacco smoke, pollutants in water, and chemicals in food. By modifying their individual behavior, people can have some control over the chemicals they absorb into their body.

Not all decisions about chemical exposure and control can be made at an individual level, however. Local, national, and global communities of people are exposed to chemicals over which they have very little individual control. People are exposed to air pollution from factories and cars or chemicals used by farmers on crops without any individual consent. To manage a community's risk from chemicals in the environment, organizations and agencies set standards to protect human health.

There are choices about chemical exposure over which individuals have control (represented by the inner circle in the adjacent diagram). Individuals also are affected by their immediate environment (their friends and family, as well as the air, soil, and water around their homes and workplaces); the middle circle of the diagram describes influences on an individual over which he or she has less control. Finally, the outer circle describes the world that surrounds individuals over which they have little control but that can have an impact on individuals. The arrows between each concentric circle indicate that individuals, their environment, and the world at large all affect each other.



One step in community risk management is to determine how much risk is acceptable to people. If the chance that exposure to a particular chemical causes cancer is only 1 in 1 million, people often are less concerned than if the chance is 1 in 10. The picture becomes more complicated when societal issues weigh in. Is the exposure voluntary (as in smoking cigarettes) or involuntary (as in pollution from a

factory)? Does it occur in the workplace or at home? Are there acceptable alternatives to the use of the toxic chemical? How would use of a safer chemical change the economic picture?[2]

To establish some individual control over community management of chemical exposure, people can choose to be involved with organizations and agencies that are concerned with the prevention of toxic chemical exposure on a community level.

Notes About Lesson 5

In this lesson, students have the opportunity to apply many of the concepts of toxicology to a scenario that involved toxic chemicals in Minamata, Japan. By looking at a situation from the 1950s, students can recognize how far scientists and the general public have come in their understanding of chemical hazards and their knowledge of how to minimize risk from these hazards. Students can begin to identify situations in their own lives in which they make conscious decisions to limit their chemical exposure and those over which they have little control.

In Advance

CD-ROM Activities	
Activity Number	**CD-ROM**
Activity 1	yes
Activity 2	no
Extension Activity	no

Photocopies		
Activity Number	**Master Number**	**Number of Copies**
Activity 1	Master 5.1, *Risk Assessment and Management* Master 5.2, *Minamata Disease*	1 transparency 1 for each student
Activity 2	Master 5.1, *Risk Assessment and Management* Master 5.2, *Minamata Disease*	1 transparency 1 for each student
Extension Activity	none	none

Materials		
Activity 1	**Activity 2**	**Extension Activity**
For the class: • CD-ROM • computer • overhead projector • transparency of Master 5.1, *Risk Assessment and Management* • plain paper **For each student:** • 1 copy of Master 5.2, *Minamata Disease*	**For the class:** • overhead projector • transparency of Master 5.1, *Risk Assessment and Management* • plain paper **For each student:** • 1 copy of Master 5.2, *Minamata Disease*	**For the class:** • current event stories students began collecting in Lesson 1, Extension Activity

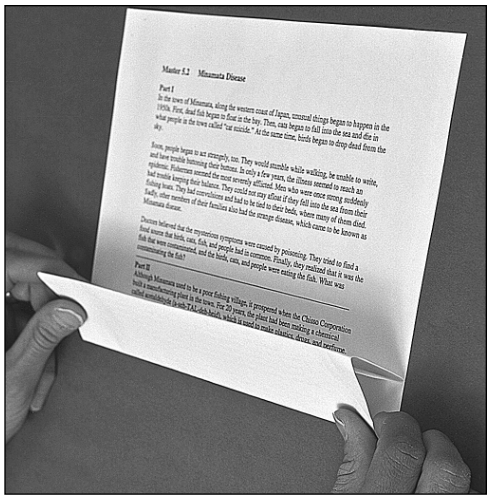
PREPARATION

Activity 1

Arrange for students to have access to computers.

Make a transparency of Master 5.1, *Risk Assessment and Management*.

Duplicate Master 5.2, *Minamata Disease*, one for each student. To allow students to read only small amounts of the information at a time, fold along the dashed lines.



Activity 2

Gather the same materials used in Activity 1.

Extension Activity

Remind students to bring in the current event stories they began collecting in Lesson 1.

Be sure to have a transparency of Master 5.1, *Risk Assessment and Management*.

Procedure

ACTIVITY 1: PEOPLE AT RISK

1. **Remind students that there are chemicals in the environment that cause health problems for humans. Tell students that toxicologists study the extent and type of health problems associated with a particular level of chemical exposure. Then, they use what they learn to assess the threat of that chemical to the health of people in particular situations. This kind of analysis is called a *risk assessment*. Display the top half of a transparency of Master 5.2, *Risk Assessment and Management*.**

2. **Distribute the folded sheets made from Master 5.2, *Minamata Disease*. Tell students that they are going to practice the steps to making a risk assessment by using a well-known case from Japan in the 1950s. Instruct students to read Part I of Master 5.2. Then, discuss the answers to the questions in Step 1 on the *Risk Assessment and Management* transparency.**

   - **Is a new health problem present?**

     Yes. Fish, cats, and birds were sick and dying. Also, people were acting strangely.

   - **What are the symptoms?**

     People were stumbling, unable to write, fumbling with their buttons, having difficulty balancing, falling from boats, suffering from convulsions, and dying.

   - **What do the affected individuals have in common?**

     Many work as fishermen or were in the families of fishermen.

Content Standard F: Students should develop understanding of personal health, natural hazards, and risks and benefits.

Minamata photographs by W. Eugene Smith and Aileen M. Smith.

Once students have answered the questions on the transparency, ask them to offer ideas about what they think was contaminating the fish.

3. Instruct students to unfold the first fold, revealing Part II. Ask them to read the paragraphs and then answer the questions in Step 2 of the Risk Assessment on the transparency.

- **What is causing the problem?**

Pollution was contaminating the fish with mercury, and people were getting sick when they ate the fish.

- **What is the source of the problem?**

The Chisso Corporation was dumping the mercury, so the company was the source of the problem. It might be interesting to discuss the role the community had in allowing the pollution of the bay to continue by accepting compensation for poor fishing conditions. Could the townspeople have demanded cleaner water instead of being satisfied with a monetary solution to the problem of fewer fish for harvest?

Once students have answered the questions on the transparency, ask them to suggest answers to the question at the end of Part II: What made this contamination of the fish so dangerous to humans?

4. Instruct students to unfold the next fold, revealing Part III. Ask students to read the paragraph and then answer the questions in Step 3 of the risk assessment.

- **What are the sources of exposure to the chemical?**

People were exposed to mercury by eating contaminated fish. The contamination of the fish was serious because it was a primary food source for the community.

- **How much exposure are people in the area receiving?**

People in Minamata, especially fishermen and their families, ate fish often. They were getting a small amount of mercury often over a period of time. Any amount of contaminated fish over 30 pounds per year is likely to provide a harmful exposure to mercury.

- **Is the exposure acute or chronic? (Is it likely to happen only once, or often over the course of time?)**

The exposure to mercury happened in Minamata over a long period of time: It was a chronic chemical exposure.

5. Ask students *not* to unfold the last fold until directed to do so during the next activity. Discuss the information from the reading and answer the concluding question on the risk assessment: How great is the risk to people?

Content Standard E: Students should develop understandings about science and technology. Perfectly designed solutions do not exist. All technological solutions have tradeoffs, such as safety, cost, efficiency, and appearance…. Technological solutions have intended benefits and unintended consequences. Some consequences can be predicted, others cannot.

Because of their dependence on fish as a primary source of food, the potential risk of mercury poisoning from contaminated fish for people living in Minamata was very high.

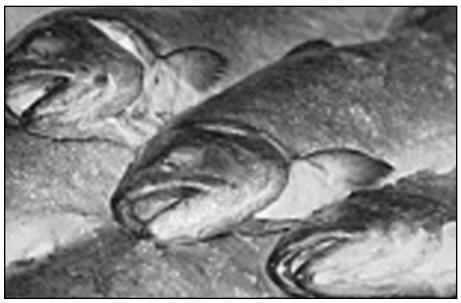


Photo: Corel

6. Play the video segment on the CD-ROM that describes the Minamata story.

Insert the CD into the computer, go to the main menu, and access *What Is the Risk?* Play the video documentary for the students.

Because the time period and geographic location of the Minamata tragedy are so far removed from students' experiences, the visual representation of the story on the CD-ROM helps it come alive for students.

ACTIVITY 2: WHAT IS *YOUR* RISK?

Photo: Corel

1. Remind students that mercury is used today in thermometers and batteries. (Although newer thermometers now use red alcohol, many old ones contain mercury.) Tell students that although they do not live in Minamata in the 1950s, inappropriate disposal of items containing mercury poses a threat to their environment, even today. Since garbage either is incinerated or covered up in landfills, mercury can make its way into the environment through emission of burning gases into the air or groundwater contamination. Fish contaminated with mercury can make their way into the food supply.

2. Ask students how they think they can avoid mercury poisoning from contaminated fish.

Most students will say that they could stop eating fish, thereby eliminating their risk just by avoiding exposure to the mercury-contaminated fish. Some students may indicate that the risk of mercury poisoning provides a great excuse to avoid a less-than-favorite food: fish.

Ask students if it is possible always to avoid a chemical in order to eliminate possible exposure. What about a chemical in the air? Could students choose not to breathe in order to avoid exposure to an air pollutant?

This question brings up the issue of control. If your food supply is varied enough, you can choose not to eat fish and still remain healthy. (This might not be an option for an island population that depends

on fish for protein.) You cannot, however, choose not to breathe as a way to avoid exposure to an air pollutant. You would need to find other ways to limit your exposure to the air pollutant, like staying inside, not exercising outside, or wearing a mask that filters the air.

3. **Tell students that one of the reasons for understanding the role of toxicology in human health is to empower the students to make choices that decrease their risk of becoming ill due to exposure to harmful chemicals. Once they know the risk from a chemical exposure, they can manage their risk by deciding how to deal with the risk. Walk the students through the steps of Risk Management on the bottom half of the transparency of Master 5.1, *Risk Assessment and Management*. Contrast the situation in Minamata, Japan in the 1950s with the life of a today's typical U.S. middle school student.**

   First, ask the students to think about risk assessment:

   - **What is a person's risk of mercury poisoning?**

   Because of their dependence on fish as a primary source of food, the potential risk for a person living in Minamata in the 1950s was high. For today's middle school students, the risk is relatively low. The average middle school student does not consume enough fish to pose a problem, and most of the fish is commercially caught in regulated waters. Only a middle school student who lived near contaminated water and regularly ate the fish from the contaminated water would be at a higher risk.

   Then, continue answering the questions in the Risk Management section of the transparency:

   - **How do the people involved perceive the risk? Are their perceptions accurate?**

   Possible answers: At first, Minamata residents did not know of the risk or worry about it. Once they began to see the effects of mercury poisoning, the Minamata residents perceived the risk as very serious. Their perceptions were accurate: Their primary food source was contaminated by industrial pollution, and that pollution was having a direct effect on the health of the community.

   Middle school students should perceive their risk as minimal. If a student perceives his or her risk as high, that perception would not be accurate according to the risk assessment above.

   - **Who is responsible for the harmful substance and its presence in the environment? What role does the responsible party have in any cleanup?**

   Allow time for students to discuss who they think was responsible for the situation in Minamata and what they think the responsible party should have done. Then, instruct them to unfold the last fold on Master 5.2 and read Part IV.

The Chisso Corporation was responsible for discharging polluted effluent into the bay. The corporation ultimately was held liable for its negligence in the 1970s. More complicated, however, are the social and economic pressures that influenced the placement of the plant in Minamata: People in the fishing village were interested in progress and enjoyed the prosperity that the industry brought to the town.

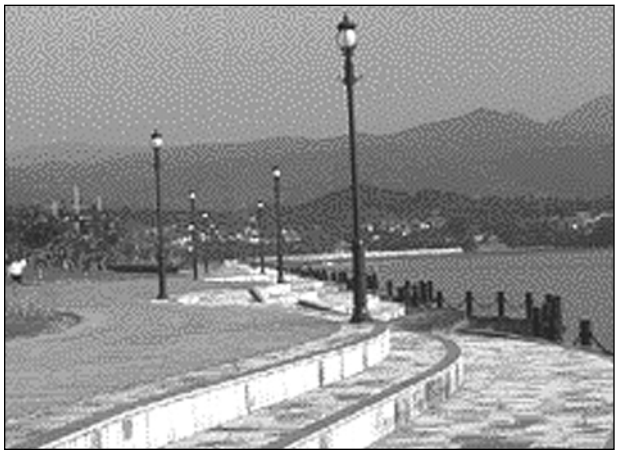
Middle school students could be indirectly responsible for some of the mercury contamination in their local area because of the way they dispose of batteries. Students and family members can take responsibility for disposing of potentially harmful materials in a safe way and using safer alternatives, such as rechargeable batteries.

- **What are the benefits and tradeoffs that a person must weigh when making a decision about the risk?**

Fish provide many health benefits to the cardiovascular system and to brain development. The dietary proteins that fish provided to the residents of Minamata were very important to good health. However, we now know that mercury poisoning from eating contaminated fish results in serious brain damage. The U.S. Environmental Protection Agency has advised that there are health benefits to eating fish and that consumption of fish should continue, but at a rate not to exceed 30 pounds per year. Because middle school students rarely reach an annual level of consumption of 30 pounds of fish, they can enjoy all the healthy benefits of eating fish without being concerned about any negative tradeoffs.

- **What action should people take to minimize their risk? Can the risk be managed by individuals, the community, and/or governments?**

In Minamata, industrial manufacture of acetaldehyde needed to stop. The corporation still operates in Minamata but produces liquid crystals, preservatives, fertilizers, and other chemicals. Over several years, 1.5 million cubic meters of contaminated sludge was dredged from the



Photos courtesy of the City of Minamata, Japan.

bay. Over the main dumping site there now are museums, memorial sites, parks, and a study center. In 1997, the water in the bay was declared safe again for fishing and swimming. People have chosen to move away from Minamata to make their living elsewhere: The town has only 70 percent of the number of people it once had.

Middle school students can eat fish sensibly, dispose of mercury-containing products safely, and support organizations that provide hazardous waste cleanup in their communities. Regulatory agencies can measure mercury contamination in fish and regulate fishing or sales of fish from contaminated waters.

Extension Activity

Before discussing the current event with the class, ask students to do a risk assessment individually. Collect students' written summaries and evaluate them for understanding of the process of assessing risk. Then discuss the students' ideas for managing the risk.

Content Standard G: Students should develop understanding of the nature of science and the history of science.

1. Review a local or current situation in which people are being exposed to a hazardous chemical. Use the *Risk Assessment and Management* transparency to discuss students' ideas about the level of risk for the community and ways to manage that risk.

Tip from the field test: This is a good time to go back to the current event articles the students have been collecting since Lesson 1. Choose one or two of the most interesting situations and assess risk for the population and decide how to manage the risk.

Because a current situation most likely will be unresolved, you will need to lead an open-ended discussion and help students recognize that there might not be answers for some of their questions at this time. This process of asking questions and not knowing the "right" answers is representative of the nature of science and scientific inquiry.